TITLE: CO_2 Mitigation through Controlled Photosynthesis

PIs: David J. Bayless, Morgan Vis and Michael Prudich

STUDENTS: Travis Anderson and Santosh Subramanium

INSTITUTION: Ohio Coal Research Center, Ohio University, Athens, OH 45701-2979
bayless@ohio.edu
740-593-2064 *voice*
740-593-0476 *fax*

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ABSTRACT

SIGNIFICANCE TO THE FOSSIL ENERGY PROGRAM

The bulk of CO_2 emissions reductions in the United States needed to meet the Kyoto Accords will likely be shouldered by the fossil-fired power generation industry, due to a number of technical and political factors. One widely considered option, the mass replacement of coal with natural gas, would eliminate the diversity in the fuel supply necessary to ensure reliable delivery and competitive pricing of electrical power. Therefore, the need to develop carbon management programs for coal-fired generation is of paramount importance. This project investigates the development of a *practical* photosynthesis-based system for CO_2 management that could complement land or water-based CO_2 sequestration, or provide a viable alternative for fossil-generation units where such sequestration would be impractical.

OBJECTIVES

This project focused on the elements to make a biologically-based (or photosynthetically-based) CO_2 remediation process practical at the scale of a typical (1000 MW) power plant. While considerable work with biological organisms has been done to understand photosynthesis, little has been done to create a containable and sustainable photosynthetic system to control CO_2 emissions of a fossil-fired unit. Issues such as lighting source, temperature, optimal carbon source, harvesting, repopulation, post-harvesting utilization, growth chamber construction, and suitability of organism strains must all be examined. This work began with specific examinations of one strain (Nostoc 86-3, μ-Nostix, Binghamton, N.Y.) and the issues of temperature, carbon source, harvesting, and repopulation.

ACCOMPLISHMENTS TO DATE

Two test reactors and incubation facilities (using a fluidized bed suspension running 5% CO_2-95% air) were constructed: one bench-scale, the other a larger test unit. The reactors have been used to demonstrate that cyanobacteria can be suspended and grown on vertical nylon membranes (to minimize pressure drop in the flue gas) at temperatures typical to pulverized coal flue gas that has been wet-scrubbed for SOx control. The process, which to-date is specific to the Nostoc 86-3 strain, is temperature and photon level sensitive, but relatively insensitive to CO_2 level in the range of 4-15%(v).

Figure 1. Carbon Recycling Facility

The reactor and support unit shown in Figure 1 was designed to test large quantities of cyanobacteria with large optical paths for light transmission (to create maximum attenuation.) The facility recirculates a simulated flue gas at constant temperature, while a surrounding lighting system provides the necessary photons for photosynthesis. Not shown in the figure is the nutrient recirculation system that also serves to repopulate the screens with developing cyanobacteria removed from the screens during harvesting.

Harvesting, or the process of removing mature organisms from the reactor, has proven to be the key area of research for this system. Mature organisms utilize carbon at a much slower rate than developing organisms. Further, reproduction of the cyanobacteria is affected by population density. Because reactor spacing is limited, productive organisms must be separated from dead or unproductive ones. Our team has identified a number of ways of identifying dead vs. live organisms using Sytox Green, which stains dead organisms. Size based selection has been less productive, but is still undergoing investigation.

Because the strain we tested proved relatively sensitive to temperature (although admittedly a mesophilic strain), it is clear that mesophilic and lower-temperature organisms utilize carbon (grow) at faster rates than typical thermophilic organisms. Thus, the need to lower flue gas temperatures. After calculations showing unacceptable associated energy losses, a new approach was taken. Instead of putting the organisms in the flue gas, the CO_2 from the exhaust was extracted by water as bicarbonate, using a process developed at Ohio University's Institute for Corrosion and Multiphase Technology. Most cyanobacteria fix carbon in the form of bicarbonates much more effectively than as CO_2. This process, while heating the bicarbonate solution to 35-40°C, significantly lowers the surrounding organism temperature, thus permitting the use of much faster growing organisms.

After limited testing with the bench scale facility, with the shortest optical paths, it became readily apparent that artificial lighting would not suffice in any practical system. Out team would never be able to independently develop the expertise for a solar light collection system. Fortunately, the Photonics and Transportation Systems Division at Oak Ridge National Labs has developed an optical tracking system for hybrid lighting of buildings that collects solar energy, filters UV and IR wavelengths for use in photovoltaics, passes the visible spectrum (critical for photosynthesis) through large core fiber optic cables to the point of utilization. We are extremely encouraged by the working relationship we have developed with ORNL and anticipate that this technology will facilitate mass growth of cyanobacteria.

PLANS FOR THE COMING YEAR

This project will not receive funding from DOE's UCR for the next year. However, continuation from other funding sources has been sought. Among the major efforts planned include

- Collaboration with Montana State University in isolating and testing new thermophilic strains
- Integration of the harvesting system to employ the Sytox technology
- Collaboration with Oak Ridge National Laboratory's Photonics and Transportation Systems Division to integrate solar collectors and the large core fiber optic delivery system with the photobioreactor to optimize organism growth

ARTICLES, PRESENTATION AND STUDENT SUPPORT

Journal Articles (peer reviewed)

- None

Presentations

- Ohio Coal Development Office University Research Consortium Contractors meeting, March 23, 2000, Athens, Ohio.

Students Supported under this Grant

- Santosh Subramanium, graduate student in Mechanical Engineering, Ohio University
- Travis Anderson, graduate student in Mechanical Engineering, Ohio University